Sizes and Grading of Aggregates for Road Maintenance and Construction

W. A. SUTTON, Field Engineer
Materials and Tests
Indiana State Highway Commission

The use of tested, sized, and graded aggregates will assure quality materials for maintenance and construction of your roads. It is not the only item one must consider, but in consideration with the other factors that provide for a good road, well-prepared, sized, and graded aggregates must be especially emphasized. In order to assist you in making a good selection, we are presenting two publications prepared by Jean Hittle, Purdue University, research engineer for the Highway Extension and Research Project for Indiana Counties. He has requested and obtained advice, including ours, in their preparation. One is "Mineral Aggregate Materials for County Road Construction," designated as Herpic Report 1-61. Along with this information one should use the second report, titled "Sizes and Grading of Aggregate for Road Construction," Herpic Report 2-61. Each of these publications contains a chart and these are reproduced here for your information and convenience. Figure 1 shows principal construction uses of aggregate road materials by sizes. Figure 2 is a tabulation of gradings for coarse and fine aggregate sizes.

These charts were prepared from the 1960 Standard Specifications of the State Highway Department of Indiana in order to provide a quick reference. A choice of numbered sizes is offered on the "use" chart by the marking "X" under the type of construction. Also an attempt was made to emphasize the more commonly used sizes with a bold-faced "X" when the multiple choice as offered covers several sizes. There are many gradation specifications one could successfully use. The reason for recommending the State Highway Department sizes to you is that they represent a contribution from both user and producer interests based upon many years of experience. They represent, accordingly, the all-Hoosier choice. You should be able to obtain State Highway Department sizes from any well-established producer. The

PRINCIPAL CONSTRUCTION USES OF AGGREGATE ROAD MATERIALS BY SIZES

1960 INDIANA STATE HIGHWAY DEPARTMENT STANDARD SPECIFICATIONS

CONSTRUCTION USE	1960 Indiana State Highway Department Standard Specifications	BASE COURSE CONSTRUCTION												SURFACE COURSE CONSTRUCTION									1960 Indiana State Highway Department Standard Specifications	CONSTRUCTION USE
		Cement Concrete Base	Waterbound Macadam Base	Hot Asphaltic Concrete Base	Bituminous Coated Aggregate Base	Bituminous Coated Aggregate Base (Dense — Graded)	Bituminous Coated Blended Aggregate Base	Road – Mix Bituminous Base	Penetration Macadam Base	Compacted Aggregate Base	Plant – Mix Aggregate Base	Compacted Aggregate Base, Widening, and Shoulders	Compacted Aggregate Shoulders	Reinforced Cement Concrete Pavement	Hot Asphaltic Concrete Surface	Bituminous Coated Blended Aggregate Surface	Bituminous Coated Aggregate Surface	Bituminous Retread Surface	Road – Mix Bituminous Surface	Road Oil Surface	Bituminous Surface Treatment	Seal Coats		
Specification Section		C1	C2	C4	C5	C6	C7	C8	C9	C10	C12	F40	F41	D1	D3	D4	D5	D7	D8	D9	D10	D12	Specification Section	
Aggregate Size No.																							Aggregate Size No	
Open Graded	1		X						X														1	Open Graded
	1F		X						X														1F	
	1W		X																				1W	
	2	X			X									X			X	X					2	
	4			X	X		X	X							X	X	X	X				X	4	
	5	X					X							X		X						X	5	
	7							X								X			X	X			7	
	8							X	X						X	X	X		X		X	X	8	
	9							X	X						X	X	X	X	X		X	X	9	
Screenings	10		X																				10	Screenings
	10FF		X							X													10FF	
	10W		X																				10W	
	11														X	X	X	X			X	X	11	
	12																			X	X	X	12	
	12C																			X	X	X	12C	
Dense Graded	53		X							X	X	X											53	Dense Graded
	53B					X		X									X		X				53B	
	63		X																				63	
	73												X										73	
Sand	14	X												X									14	Sand
	15																						15	
	16														X								16	
	17			X			X								X	X							17	

X Major usage under Standard Specifications for construction item indicated
X Minor usage under Standard Specifications for construction item indicated

IMPORTANT NOTE: Consult the 1960 ISHD Standard Specifications for applicable details of materials and construction.

COMPILED AND DISTRIBUTED BY HERPIC

Fig. 1.

GRADING OF COARSE AGGREGATE SIZES

1960 INDIANA STATE HIGHWAY DEPARTMENT STANDARD SPECIFICATIONS – SECTION K3

Aggregate Size No.	TOTAL PER CENTS PASSING SIEVES HAVING SQUARE OPENINGS															Aggregate Size No.
	4"	3-1/2"	3"	2-1/2"	2"	1-1/2"	1"	3/4"	1/2"	3/8"	No. 4	No. 8	No. 30	No. 100	No. 200	
1		100	–	45-85	0-25	0-10	0-5	0-2								1
1F			100	60-90	0-45	0-15	0-5	0-2								1F
1W	100	90-100	–	25-60	–	0-15	–	0-5								1W
2				100	95-100	–	0-20	0-5	0-2							2
4						100	70-90	40-70	10-30	–	0-5	0-2				4
5						100	85-98	60-85	30-60	–	0-10	0-5				5
7							100	65-95	25-80	–	0-15	0-10	0-5			7
8							100	85-100	20-60	–	0-5	0-2				8
9								100	65-90	–	0-10	–	0-2			9
10								100	65-90	–	20-60	10-30	0-10			10
10FF								100	85-100	–	40-80	15-50	0-30			10FF
10W									100	90-100	–	–	–	10-30		10W
11									100	75-95	5-20	0-5				11
12									100	–	50-80	0-35	0-4			12
12C									100	–	25-55	0-20	0-4			12C
53						100	80-100	70-90	55-80	–	35-60	25-50	15-30	–	5-10	53
53B						100	80-100	70-90	55-80	–	35-60	25-50	15-30	–	0-5	53B
63						100	95-100	75-90	50-80	–	25-55	–	10-25			63
73							100	90-100	60-90	–	35-60	–	15-30	–	5-10	73

Fig. 2.

GRADING OF FINE AGGREGATE SIZES

1960 INDIANA STATE HIGHWAY DEPARTMENT STANDARD SPECIFICATIONS – SECTION J6

Aggregate Size No.	SCREEN SIZES (SQUARE OPENINGS) AND TOTAL PER CENT PASSING										Aggregate Size No.
	1/2"	3/8"	No. 4 .187"	No. 6 .132"	No. 8 .0937"	No. 30 .0232"	No. 50 .0117"	No. 80 .0070"	No. 100 .0059"	No. 200 .0029"	
14-No. 1	–	100	95-100	–	80-95	20-50	5-20	–	0-5	–	14-No. 1
14-No. 2	–	100	95-100	–	80-95	25-55	10-30	–	2-10	–	14-No. 2
15	–	–	–	100	90-100	50-75	15-40	–	0-10	–	15
16	–	–	–	–	–	100	–	95-100	–	65-100	16

Asphalt Sand		FRACTIONAL PER CENT BETWEEN SQUARE-OPENING SIEVES								Asphalt Sand
	Passing No. 4	4–8	8–16	8–40	16–50	40–80	50–100	80–200	100–200	Passing No. 200	
17	100	0-10	15-35	–	25-65	–	5-35	–	1-10	0-5	17
18	100	0-5	–	12-40	–	25-60	–	25-45	–	0-5	18

COMPILED AND DISTRIBUTED BY HERPIC

aggregate will be controlled for uniformity of sizing. If you offer the producer enough quantity of a special size, he will attempt to accommodate you. But if you use State Highway size numbers he will be better able to service your needs inasmuch as he stocks these sizes. Also, as you know, getting something made special often results in delay and increased costs.

Control of these sizes and gradations is by means of test sieves. For our State Highway material, an inspector with a set of scales and sieves samples the aggregate and separates it into various sizes using the sized sieves. He then weighs the various fractions and calculates whether the required percentage amounts passing the test sieves used are within the required limits of Figure 2. Producers in many instances are gradation-minded enough that they test their product with test sieves without relying on the State Highway inspectors. If you will state, "I want State Highway Department No. 9," the producer will understand your needs better. If No. 9 is marked "X" on the intended "use" chart for the purpose, its use will go a long way towards the work being successful in having the right sizing for the job.

Producers use plant screens with square openings properly selected to make the required gradation size. From coarse to fine for the various size numbers, the producer may use 4-inch, 3½-inch, 2½-inch, 2-inch, 1½-inch, 1-inch, ¾-inch, ½-inch, ⅜-inch and No. 4 square-opening sieves. There is an arbitrary line drawn between coarse aggregate and fine aggregate at the No. 4 sieve, or approximately $\frac{3}{16}$-inch square opening. Coarse aggregate has most of the product rationed on a No. 4 sieve and fine aggreate, like sand, passes a No. 4 sieve. This arbitrary line explains our having coarse-aggregate and fine-aggreate tables for gradation. There is also a top size and a bottom size as applied to screens used by the producer, but for uniformity we have placed controls on certain in-between sizes. He may have to use certain intermediate sizes to meet our requirements. With fine aggregate we use sieve sizes such as No. 6, No. 8, No. 16, No. 30, No. 50, and No. 200 to control the intermediate gradation, even though the No. 8 is about the finest sieve the producer can use in a production operation.

It has been our experience in the past that we get about as good aggregates as the quality of our inspection, but with improved equipment there is greater willingness on the part of producers to make properly-graded material. Very few, indeed, adopt the attitude any more that stone is stone and gravel is gravel. You may not have the time or money to perform gradation tests on your material, although

you should. If you will call for a numbered size, any attempts to supply completely off-size material will be visually apparent. However, do not commit the error of assuming that visual inspection is a substitute for a sieve analysis. If this were possible, no one would need to run sieve analyses to insure obtaining required sizing. Between certain materials, especially gravel with rounded pieces and crushed stone in which the pieces may be more elongated, it appears visually that the stone has coarser sizing. When the sieve test is applied one learns the need for more than visual inspection. The gradation tables permit the purchaser to declare the overall sizing wanted, and furnish a standard for production and a basis for inspection to get it. They accordingly simplify buying and supplying and remove guess work as to what is wanted. Specifying the size of the aggregate for the job then becomes a very important decision for the purchaser.

Coarse aggregates are classified as open-graded and dense-graded. One of the difficulties with use is a tendency of aggregate sizes to segregate in handling. This tendency is pronounced with dense-graded aggregates. A well-tested, acceptable aggregate when stockpiled in cone-like stockpiles may easily be separated into coarse and fine. When dump, dropped or otherwise rolled in handling, the large material moves to the outside, leaving the fine in the center. The longer the gradation from coarse to fine, especially in dense-graded material, the greater the tendency to segregate. It is necessary in use, where combinations of coarse and fine aggregate are wanted in the finished work, to combine them separately. For example, in portland cement concrete one or more sizes of coarse aggregate are separately batched with the fine aggregate to get uniformity in the final mixture. The proportions of coarse and fine aggregate must be carefully controlled to get the maximum advantage with the minimum portland cement.

It is usually a good idea to use as large a top size aggregate as the use will permit. For example, the State Highway Department may select No. 2 (2-inch top size), No. 5 (1-inch top size), and No. 14 sand for portland cement concrete pavement. Two-inch is the maximum size that can be conveniently worked for paving. For structures where much steel reinforcing is used o. 5, or 1-inch top size, is preferred for placing around the reinforcing. There is much mass concrete in dams where even larger sizes, up to 5-inch and 6-inch, are used to provide savings in sand and cement. We are advocating selection of the largest aggregate size that can be conveniently handled. In bituminous work the top size usually should not be larger than one-half the thickness of the finished course. No explanation is needed for the

fact that one cannot successfully put a two-inch piece in a one-inch course. For a 1-inch course, ½-inch top size would be safest, with ¾-inch as the maximum.

The subject of aggregate sizes applies not only for new construction but also for maintenance. Deep chuck holes may be advantageously filled with 1½-inch or larger top size aggregate, like No. 63, No. 53, No. 4, or No. 2. Many thin patches will not accommodate over a size No. 11, which is a ½-inch top size aggregate. For thicker repairs, however, larger aggregate is better due to the added strength. Aggregates for bituminous concrete are also batched, coarse and fine separately, in order to prevent segregation and to obtain a more positive and uniform gradation control. It would be a good idea to separate the coarse and fine in aggregate sizes like No. 53, No. 63, and No. 73 and recombine if it were not for economical considerations. When made as one size, the handling to prevent segregation becomes a serious problem. Addition of a controlled amount of water will aid materially in preventing this condition.

Final use in the road dictates combining coarse and fine material for most types of construction. Even waterbound and penetration macadams that start with very coarse, open-graded sizes for initial application use finer sizes for filling or choking the voids or cavities that are left after compacting the coarse sizes. It has been recognized for many years that both portland cement concrete and bituminous concrete are successful only if properly proportioned with uniformly-graded coarse and fine aggregate. More recently it has been demonstrated that similar gradation control for size and uniformity pays off in base construction where limited amounts of soil binder, bituminous material, portland cement, calcium chloride, sodium chloride, lime and fly ash, or whatever one prefers to assist the inherent binding qualities of the aggregate, are used.

This discussion has been limited, and we do not feel that we have explained all the possible advantages that come with sizing and grading aggregates. Much time and discussion could be devoted to the No. 200 sieve material alone and its importance to bituminous concrete, sheet asphalt, portland cement concrete, and the dense-graded, traffic-bound gradations. This material is almost flour-like in size and may be beneficial or harmful depending on quality and amounts used.

To sum up our discussion, it has been our hope to explain the need for graded and sized aggregates that are only obtained from a producer who is equipped with proper sizing equipment. We have

attempted to explain the meaning of gradation sizes and the use of sieve sizes for controlling top size and gradation limits. The importance of ordering and using the correct size of aggregates to fit the job, and of insuring by testing that the size requirements are met, has been emphasized. We have hoped to make you gradation and size minded, and are sure you will enjoy the benefits of better work if you select, order, and get your aggregates by the correct State Highway Department size number.